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Notes on three closely related species of the genus *Pimoa* (Araneae, Pimoidae) from Southwest China

Bing Wang[1], Qingzhen Meng[1], Zhiyuan Yao[1], Xiaoqing Zhang[1]

1 *College of Life Science, Shenyang Normal University, Shenyang 110034, Liaoning, China*

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Corresponding authors: Zhiyuan Yao (yaozy@synu.edu.cn); Xiaoqing Zhang (zhangxq@synu.edu.cn)

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Abstract

The genus *Pimoa* Chamberlin & Ivie, 1943, is highly diverse and currently contains 85 species, of which 67 are distributed in Asia. In this study, a new species of *Pimoa* is described from Southwest China: *P. shimian* Wang, Yao & Zhang, **sp. nov.** (♂♀). This new species is closely related to *P. bomi* Zhang & Li, 2021, and *P. reniformis* Xu & Li, 2007. The taxonomic keys for distinguishing these three closely related species and a distribution map of all Asian pimoids are also provided.

Key Words

Asia, biodiversity, invertebrate, morphology, taxonomy

Introduction

The Pimoidae Wunderlich, 1986, is currently known to be a sister lineage of the Linyphiidae Blackwall, 1859. Pimoidae once included four genera: *Nanoa* Hormiga, Buckle & Scharff, 2005; *Pimoa* Chamberlin & Ivie, 1943; *Putaoa* Hormiga & Tu, 2008; and *Weintrauboa* Hormiga, 2003 (Xu et al. 2021). However, based on molecular and morphological data, Hormiga et al. (2021) revised the classification of this family, transferring *Putaoa* and *Weintrauboa* to Linyphiidae. Therefore, Pimoidae currently contains 86 extant species, belonging to two genera: *Pimoa* and *Nanoa* (WSC 2024). Despite significant morphological differences between *Nanoa* and *Pimoa*, previous research has supported the idea that these two genera are sister groups (Hormiga et al. 2005, 2021). Species of the monotypic genus *Nanoa* are distributed only in the West of the Rockies, USA. *Pimoa* is the most species-rich genus in Pimoidae, with 85 species distributed disjunctly across three mountainous regions of the Northern Hemisphere: the western Nearctic (from Washington to California), the western Mediterranean, and Asia (from the Himalaya to Beijing) (Lin et al. 2023). For the global transoceanic disjunctions of pimoids, Wang et al. (2008) proposed that vicariance, driven by the breakup of Laurasia, played a major role in shaping the distribution pattern. Hormiga et al. (2021) proposed that pimoids were originally distributed in the ancestral boreotropical forests of the northern latitudes. Post-Eocene gradual cooling and aridification led to the retreat of those ancestral forests, resulting in the fragmentation of pimoid distributions.

Pimoids were once considered a relict lineage and had long been considered to exhibit low species diversity (Hormiga 1994). By 2019, only four pimoid species were known to occur in the Alps and Pyrenees (Mammola et al. 2016), 15 in the West of the Rockies (Hormiga and Lew 2014), and 12 in Asia (Zhang and Li 2019). However, in recent years, an unexpectedly high diversity of *Pimoa* (54 species) has been revealed in the Pan-Himalayan region (Himalayas, Tibet, and Hengduan Mountains), leading to its recognition as the diversity center for Pimoidae, accounting for 76% of the total diversity (Xu et al. 2021; Irfan et al. 2022). Among Asian pimoids, China exhibits remarkable diversity, with 49 species recorded to date. Therefore, we recently conducted a field survey targeting pimoids in Southwest China and discovered a new species of *Pimoa* (Fig. 1). In this paper, we have photographed and described this new species. Additionally, we

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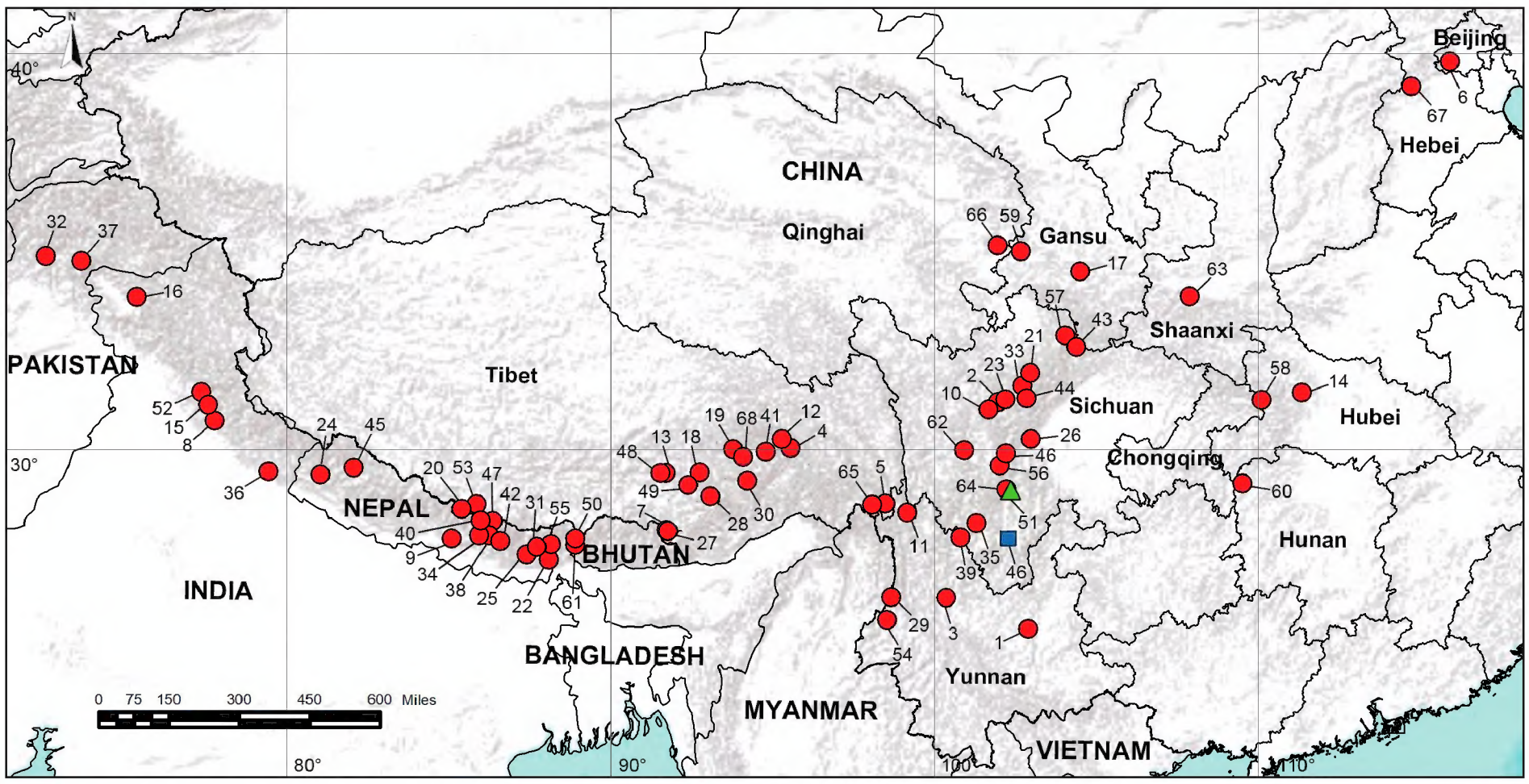

Figure 1. Distribution records of all Asian pimoids. The green triangle represents *Pimoa shimian* sp. nov., the blue rectangle represents a new record of *P. reniformis*, and red dots represent the type localities of 67 known species. **1** *P. anatolica* Hormiga, 1994 **2** *P. anning* Zhang & Li, 2021 **3** *P. binchuanensis* Zhang & Li, 2019 **4** *P. bomi* Zhang & Li, 2021 **5** *P. cawarong* Zhang & Li, 2021 **6** *P. clavata* Xu & Li, 2007 **7** *P. cona* Zhang & Li, 2020 **8** *P. crispa* Fage, 1946 **9** *P. daman* Zhang & Li, 2021 **10** *P. danba* Zhang & Li, 2021 **11** *P. deqen* Zhang & Li, 2021 **12** *P. dongjiu* Zhang & Li, 2021 **13** *P. duiba* Zhang & Li, 2020 **14** *P. exigua* Irfan, Wang & Zhang, 2021 **15** *P. gagna* Zhang & Li, 2021 **16** *P. gandhii* Hormiga, 1994 **17** *P. guiqing* Zhang & Li, 2021 **18** *P. gyaca* Zhang & Li, 2021 **19** *P. gyara* Zhang & Li, 2021 **20** *P. gyirong* Zhang & Li, 2021 **21** *P. heishui* Zhang & Li, 2021 **22** *P. indiscreta* Hormiga, 1994 **23** *P. jinchuan* Zhang & Li, 2021 **24** *P. khaptad* Zhang & Li, 2021 **25** *P. koshi* Zhang & Li, 2021 **26** *P. lata* Xu & Li, 2009 **27** *P. lemenba* Zhang & Li, 2020 **28** *P. lhatog* Zhang & Li, 2021 **29** *P. lihengae* Griswold, Long & Hormiga, 1999 **30** *P. mainling* Zhang & Li, 2020 **31** *P. mechi* Zhang & Li, 2021 **32** *P. miandam* Zhang & Li, 2021 **33** *P. miero* Zhang & Li, 2021 **34** *P. mude* Zhang & Li, 2021 **35** *P. muli* Zhang & Li, 2021 **36** *P. nainital* Zhang & Li, 2021 **37** *P. naran* Zhang & Li, 2021 **38** *P. nematoides* Hormiga, 1994 **39** *P. ninglang* Zhang & Li, 2021 **40** *P. nyalam* Zhang & Li, 2021 **41** *P. nyingchi* Zhang & Li, 2020 **42** *P. phaplu* Zhang & Li, 2021 **43** *P. pingwuensis* Irfan, Wang, Zhao & Zhang, 2022 **44** *P. putou* Zhang & Li, 2021 **45** *P. rara* Zhang & Li, 2021 **46** *P. reniformis* Xu & Li, 2007 **47** *P. rongxar* Zhang & Li, 2020 **48** *P. samyai* Zhang & Li, 2020 **49** *P. sangri* Zhang & Li, 2021 **50** *P. shigatse* Zhang & Li, 2021 **51** *P. shimian* sp. nov. **52** *P. shoja* Zhang & Li, 2021 **53** *P. sinuosa* Hormiga, 1994 **54** *P. tengchong* Zhang & Li, 2021 **55** *P. thaleri* Trotta, 2009 **56** *P. trifurcata* Xu & Li, 2007 **57** *P. wanglangensis* Yuan, Zhao & Zhang, 2019 **58** *P. wulipoensis* Irfan, Wang & Zhang, 2021 **59** *P. xiahe* Zhang & Li, 2021 **60** *P. xinjianensis* Zhang & Li, 2019 **61** *P. yadong* Zhang & Li, 2020 **62** *P. yajiangensis* Irfan, Wang, Zhao & Zhang, 2022 **63** *P. yejiei* Zhang & Li, 2021 **64** *P. yele* Zhang & Li, 2021 **65** *P. zayu* Zhang & Li, 2021 **66** *P. zekogensis* Irfan, Wang, Zhao & Zhang, 2022 **67** *P. zeluni* Lin & Li, 2023 **68** *P. zhigangi* Zhang & Li, 2021.

provide taxonomic keys to distinguish it from two other morphologically similar species that also occur in Southwest China.

Materials and methods

Specimens were examined with a LEICA M205C stereomicroscope. Images were captured with a Canon EOS 750D wide-zoom digital camera (24.2 megapixels) mounted on the stereomicroscope mentioned above and assembled using Helicon Focus v. 3.10.3 image stacking software (Khmelik et al. 2005). Epigyne and male palp were examined after dissection. The left palp was illustrated. Epigyne was removed and treated in a warmed 10% potassium hydroxide (KOH) solution.

All measurements were obtained using a LEICA M205C stereomicroscope and are given in millimeters. We measured the length of the legs and body using an ocular micrometer. Eye sizes were measured as the maximum diameter from either dorsal or frontal views. Leg measurements are shown as total length (femur, patella + tibia, metatarsus, tarsus). The terminology used in the text and the figure legends follows Hormiga (1994). The distribution map was generated with ArcGIS v. 10.2 (ESRI Inc.). Abbreviations used in this paper and in the figure legends: **ALE** = anterior lateral eye, **AME** = anterior median eye, **AME–ALE** = distance between AME and ALE, **AME–AME** = distance between AMEs, **AS** = alveolar sclerite, **C** = conductor, **CD** = copulatory duct, **CDP** = cymbial denticulate process, **CO** = copulatory opening, **DP** = dorsal plate of the epigyne, **E** = embolus, **FD** = fertilization duct, **MA** = median apophysis, **P** = paracymbium, **PCS** = pimoid cymbial sclerite, **PEP** = pimoid embolic process, **PLE** = posterior lateral eye, **PME** = posterior median eye, **PME–PLE** = distance

between PME and PLE, **PME–PME** = distance between PMEs, **S** = spermatheca, **T** = tegulum, **VP** = ventral plate of epigyne. All specimens are deposited in the College of Life Science, Shenyang Normal University (SYNU) in Liaoning, China.

Taxonomy

Family Pimoidae Wunderlich, 1986

Genus *Pimoa* Chamberlin & Ivie, 1943

Pimoa: Chamberlin and Ivie 1943: 9; Hormiga 1994: 4; Hormiga and Lew 2014: 1; Mammola et al. 2016: 1.

Note. In 1943, Chamberlin and Ivie erected the genus *Pimoa*, which included four pimoid North American species that had previously been placed within the genus *Labulla* Simon, 1915, plus three new North American species. Then, Hormiga (1993) synonymized *Louisfagea* Brignoli, 1971, with *Pimoa*, raised Pimoinae Wunderlich, 1986, to family rank, and brought an end to the history of pimoids being placed in different families.

Diagnosis. *Pimoa* (total length ranges from 4.00–12.0 mm) is larger in size than *Nanoa* (1.42–1.65 mm). The males of *Pimoa* can be distinguished from *Nanoa* by the long and membranous pimoid embolic process and the elongate cymbial denticulate process with many cuspules (vs. the pimoid embolic process absent and short cymbial process only with one strong cuspule) (Fig. 2; Hormiga et al. 2005: figs 1, 2). The females of *Pimoa* can be distinguished from *Nanoa* by the absence of a ventral scape-like septum (vs. epigynum with a distinct septum) (Fig. 3A; Hormiga et al. 2005: figs 3, 5).

Composition. The 85 *Pimoa* species are known from the northern hemisphere, with 14 from the western Nearctic, four from the western Mediterranean (Italy, France, and Spain), two from Pakistan, seven from India, nine from Nepal, and 49 from China (WSC 2024).

Type species. *Labulla hespera* Gertsch & Ivie, 1936, from California, USA.

Identification keys to three closely related species from Southwest China

Males

1 Tegulum with pointed apophysis; pimoid cymbial sclerite nearly U-shaped (Fig. 2) ..... *P. shimian* sp. nov.
– Tegulum without apophysis; pimoid cymbial sclerite nearly V-shaped (Fig. 4) 2
2 Cymbial denticulate process short and broad; paracymbium short, ca. 1/5 of cymbial length, finger-shaped (Fig. 4A, C, E) ..... *P. bomi*
– Cymbial denticulate process narrow and distally curved; paracymbium short, ca. 1/4 of cymbial length, hook-shaped (Fig. 4B, D, F) ..... *P. reniformis*

Females

1 Spermathecae separated by ca. 1/3 the width of a spermatheca; dorsal plate narrow and distally blunt (Fig. 3A, B) .... *P. shimian* sp. nov.
– Spermathecae unseparated; dorsal plate broad and distally pointed (Fig. 5) 2
2 Spermathecae round; copulatory ducts linear and with 3 strong turns (Fig. 5A, B, E, F) ..... *P. bomi*
– Spermathecae nearly bean-shaped; copulatory ducts broad, with 2 strong turns and with posterior part narrower than 1/4 width of anterior part (Fig. 5C, D, G, H) ..... *P. reniformis*

Pimoa shimian Wang, Yao & Zhang, sp. nov.

https://zoobank.org/CFB33616-E7C4-4C08-96D0-49084080022C

Figs 1–3

Type material. • ***Holotype***: • ♂ (SYNU-Ar00445), China, Sichuan, Yaan, Shimian Co., Liziping Vill., Menghuocheng Scenic Spot, Red Rock Beach (28.908262°N, 102.358586°E, 2651 m), 9 Jun. 2024, X. Zhang et al. leg. • ***Paratypes***: • 2♀ (SYNU-Ar00446–47), same data as for the holotype.

Etymology. The specific name refers to the type locality; noun in apposition.

Diagnosis. The male of *Pimoa shimian* sp. nov. resembles those of *P. bomi* (Fig. 4A, C, E; Xu et al. 2021: 9, figs 3, 54B) and *P. reniformis* (Fig. 4B, D, F; Xu and Li 2007: 493, figs 36–41), but can be distinguished by the tegulum (T) with pointed apophysis (blue arrow in Fig. 2B) (vs. tegulum without apophysis, Fig. 4C, D) and by the U-shaped pimoid cymbial sclerite (PCS, Fig. 2B) (vs. V-shaped, Fig. 4C–F). The female of *P. shimian* sp. nov. resembles those of *P. bomi* (Fig. 5A, B, E, F; Xu et al. 2021: 9, fig. 4A, B) and *P. reniformis* (Fig. 5C, D, G, H; Xu and Li 2007: 493, figs 42–47), but can be distinguished by the distally broad dorsal plate (DP), posterior part about 1/2 width of middle part (Fig. 3A, B) (vs. distally narrow dorsal plate, posterior part about 1/3 width of middle part, Fig. 5E, G) and the spermathecae (S) separated by ca. 1/3 a spermathecal width (Fig. 3A, B) (vs. spermathecae unseparated, Fig. 5A, C).

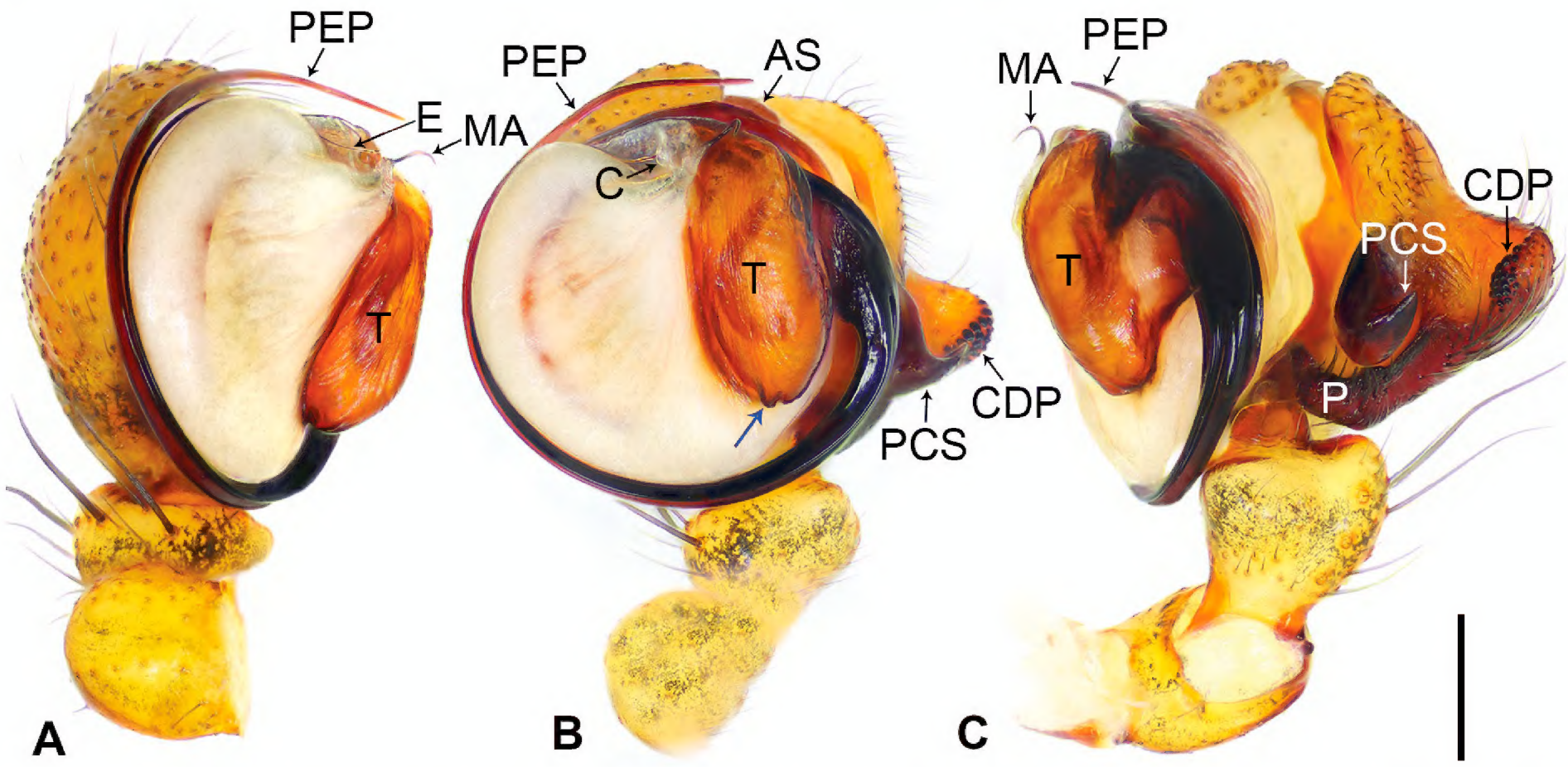

Figure 2. Left palp of *Pimoa shimian* sp. nov., holotype **A.** Prolateral view; **B.** Ventral view; **C.** Retrolateral view. Abbreviations: AS = alveolar sclerite; C = conductor; CDP = cymbial denticulate process; E = embolus; MA = median apophysis; P = paracymbium; PCS = pimoid cymbial sclerite; PEP = pimoid embolic process; T = tegulum. The blue arrow represents the tegular apophysis. Scale bar: 0.50 mm (**A–C**).

Description. Male (holotype): Total length 6.11. Carapace 3.52 long, 2.91 wide. Abdomen 2.61 long, 2.34 wide. Eye sizes and interdistances: AME 0.17, ALE 0.20, PME 0.18, PLE 0.19, AME–AME 0.12, AME–ALE 0.13, PME–PME 0.15, PME–PLE 0.18. Leg measurements: I: 22.11 (6.15, 7.24, 5.90, 2.82); II: 18.40 (5.13, 6.22, 4.87, 2.18); III: 12.37 (3.91, 3.97, 3.53, 0.96); IV: 15.96 (4.87, 5.45, 4.49, 1.15). Habitus as in Fig. 3E. Carapace yellowish with black lateral margins; thoracic fovea and radial grooves distinct; sternum brownish. Cheliceral stridulatory striae present. Abdomen black with yellowish transverse chevrons. Legs brownish with black annulations. Palp (Fig. 2A–C): patella short, almost as long as tibial; tibia short, ca. 1/2 of cymbial length, with several macrosetae and dorsal process; cymbium length/width: 0.91/1.07; paracymbium (P) short, ca. 1/4 of cymbial length, finger-shaped; pimoid cymbial sclerite (PCS) U-shaped, ca. 1/3 of cymbial length; cymbial denticulate process (CDP) broad and curved distally, with more than 20 cuspules; median apophysis (MA) slender (length/width ratio: ca. 15); conductor (C) indistinct; pimoid embolic process (PEP) longer than embolus; embolus (E) beginning at 3:00 o'clock position and terminates at 2:00 o'clock; embolic tooth absent.

Female (paratype): Total length 10.78. Carapace 3.60 long, 2.92 wide. Abdomen 7.21 long, 5.58 wide. Eye sizes and interdistances: AME 0.18, ALE 0.20, PME 0.20, PLE 0.19, AME–AME 0.17, AME–ALE 0.15, PME–PME 0.16, PME–PLE 0.15. Leg measurements: I: 19.82 (5.51, 6.86, 4.94, 2.51); II: 16.47 (4.74, 5.58, 4.23, 1.92); III: 12.69 (3.65, 4.55, 3.08, 1.41); IV: 15.57 (4.74, 5.19, 3.97, 1.67). Habitus as in Fig. 3F, G. Carapace yellowish with black lateral margins; thoracic fovea and radial grooves distinct; sternum brownish. Cheliceral stridulatory striae vestigial. Abdomen black with yellowish transverse chevrons. Legs brownish with black annulations.

Epigyne (Fig. 3A–D): trapezoidal; ventral plate (VP) broad (length subequal to width); dorsal plate (DP) tongue-shaped; copulatory openings (COs) distinct; spermathecae (S) nearly bean-shaped, separated by ca. 1/3 their width; fertilization ducts (FDs) yellowish, laterally oriented.

Distribution. Known only from the type locality, Sichuan, China (Fig. 1).

Pimoa bomi Zhang & Li, 2021

Figs 1, 4A, C, E, 5A, B, E, F

Pimoa bomi Zhang & Li, in Xu et al. 2021: 9, figs 3, 4, 54B (♂♀).

Type material examined. ***Holotype*:** • ♂ (IZCAS-Ar41925), **China**, Tibet, Nyingchi, Bomi Co., Karlung Vill. (30.04°N, 95.56°E, 3147 m), 26 Jul. 2019, X. Zhang et al. leg. ***Paratypes*:** • 1♂2♀ (IZCAS-Ar41926-Ar41928), same data as holotype.

Note. Cheliceral stridulatory striae present in the male, vestigial in the female.

Pimoa reniformis Xu & Li, 2007

Figs 1, 4B, D, F, 5C, D, G, H

Pimoa reniformis Xu & Li, 2007: 493, figs 36–47 (♂♀).

Type material. ***Holotype*:** • ♂, **China**, Sichuan, Luding Co., Hailuogou Valley (29.9°N, 102.2°E), 22 Jul. 2004, L. Tu leg. ***Paratypes*:** • 2♀, same data as for holotype • 1♂2♀, Kangding Co., road from Yerenhai to Qisehai

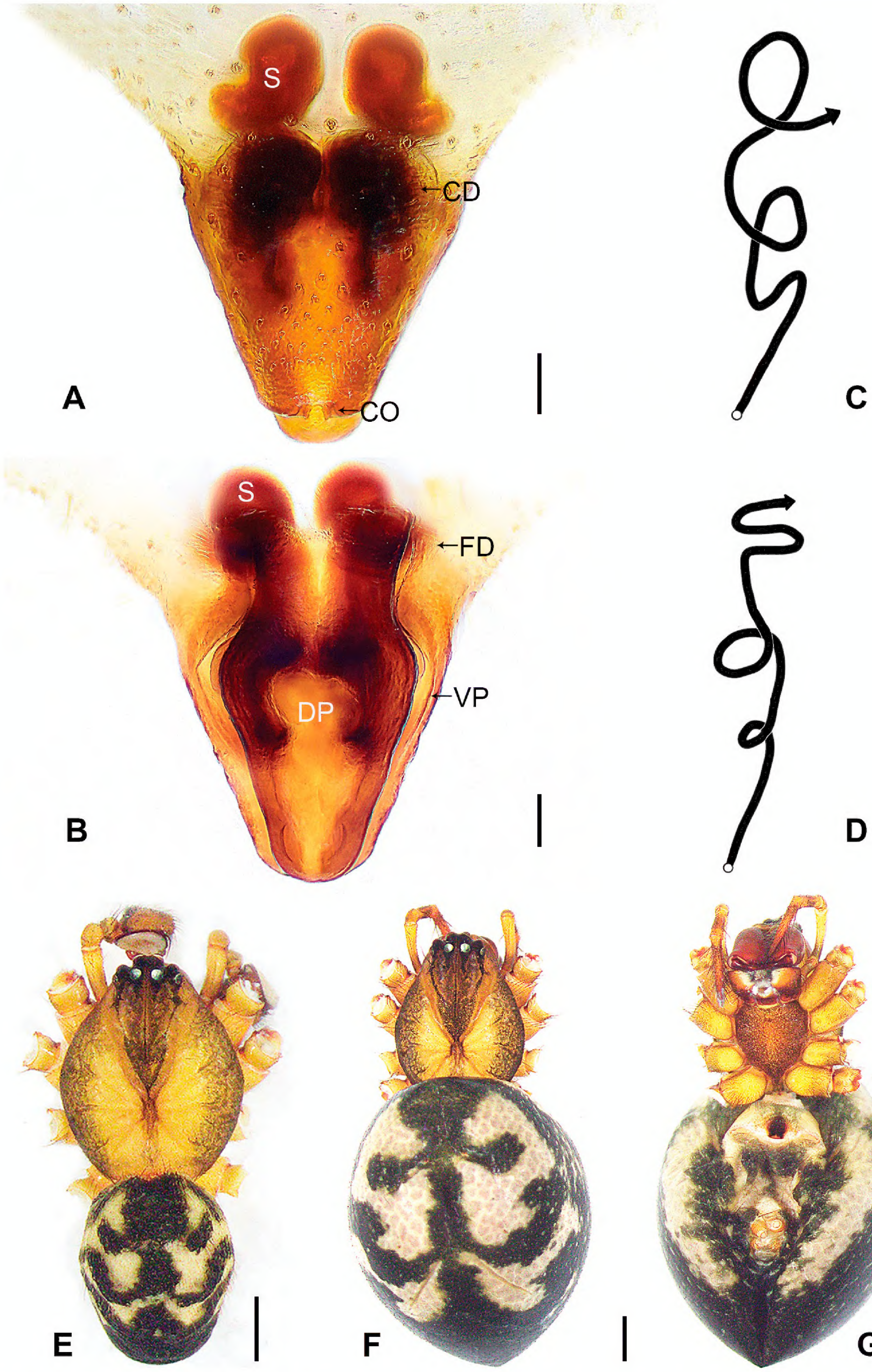

Figure 3. Epigyne and habitus of *Pimoa shimian* sp. nov., female paratype and male holotype **A.** Epigyne, ventral view; **B.** Vulva, dorsal view; **C.** Schematic course of internal copulatory duct system, ventral view; **D.** Schematic course of internal copulatory duct system, dorsal view; **E.** Male habitus, dorsal view; **F.** Female habitus, dorsal view; **G.** Female habitus, ventral view. Abbreviations: CD = copulatory duct; CO = copulatory opening; DP = dorsal plate of the epigyne; FD = fertilization duct; S = spermatheca; VP = ventral plate of epigyne. Scale bars: 0.10 mm (**A–D**); 1.00 mm (**E–G**).

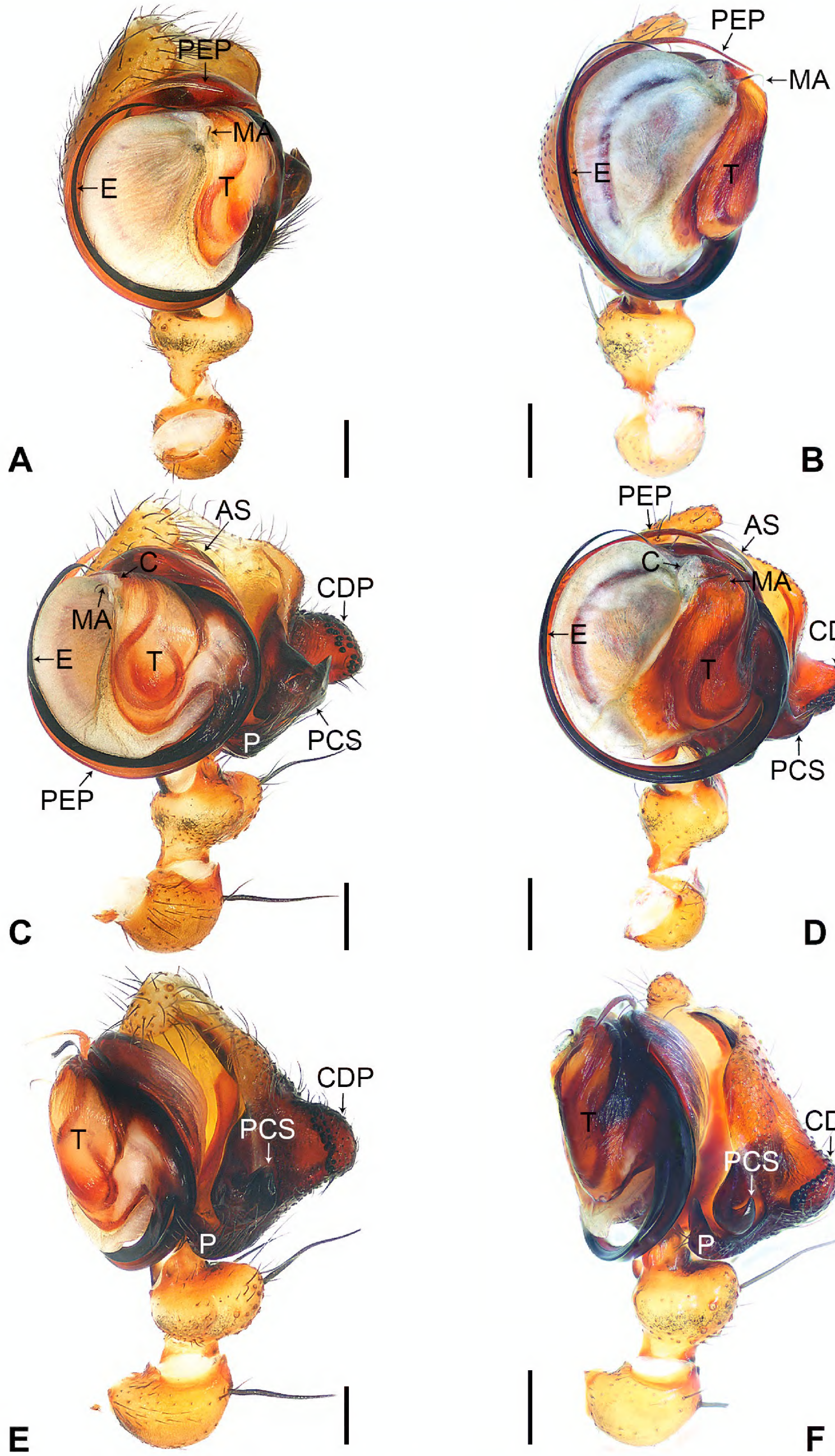

Figure 4. *Pimoa bomi* (**A, C, E**), *P. reniformis* (**B, D, F**) **A, B.** Prolateral view; **C, D.** Ventral view; **E, F.** Retrolateral view. Abbreviations: AS = alveolar sclerite; C = conductor; CDP = cymbial denticulate process; E = embolus; MA = median apophysis; P = paracymbium; PCS = pimoid cymbial sclerite; PEP = pimoid embolic process; T = tegulum. **A, C, E** were modified from Xu et al. (2021). Scale bars: 0.30 mm (**A–F**).

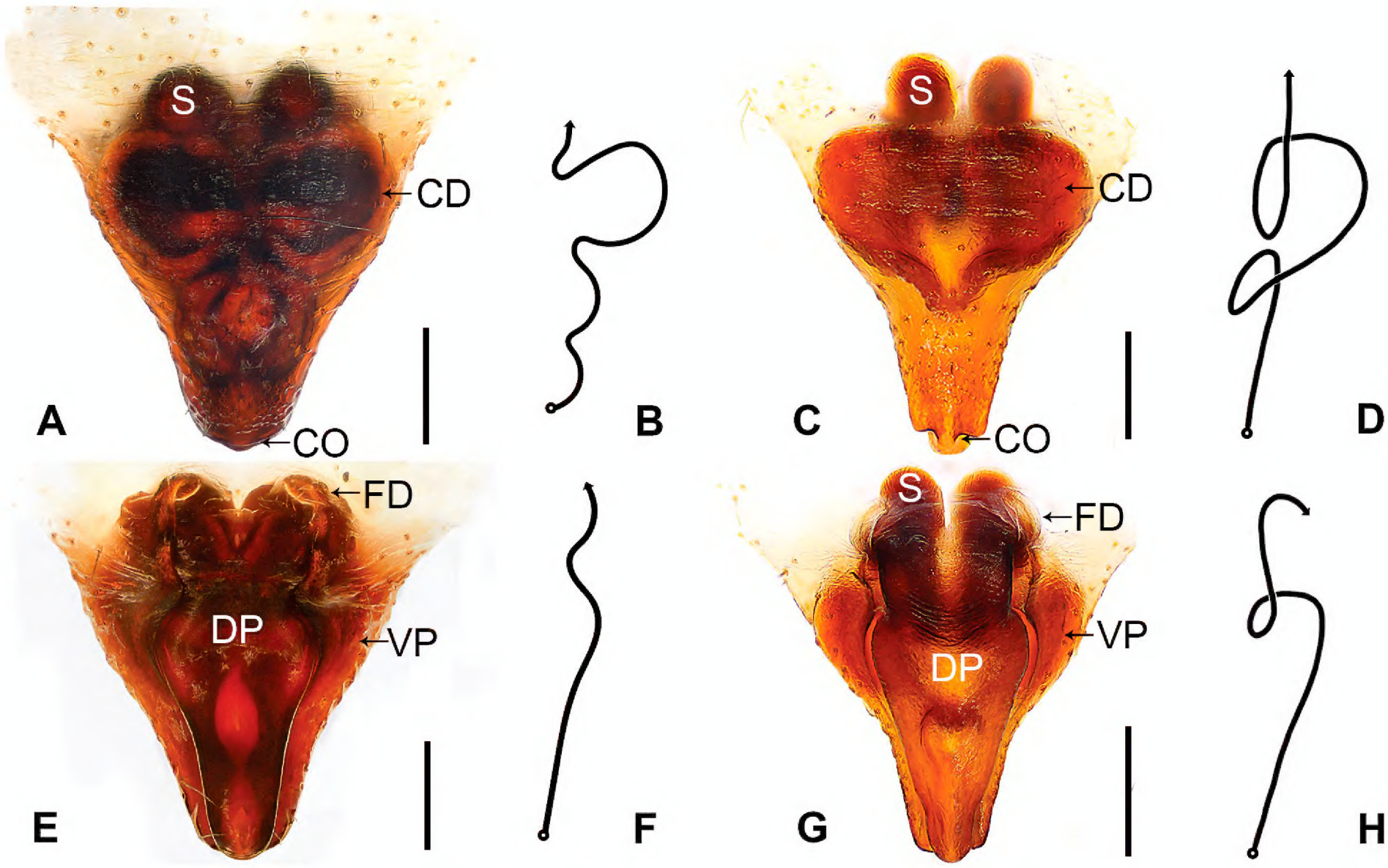

Figure 5. *Pimoa bomi* (**A, B, E, F**), *P. reniformis* (**C, D, G, H**) **A, C.** Epigyne, ventral view; **B, D.** Schematic course of internal copulatory duct system, ventral view; **E, G.** Vulva, dorsal view; **F, H.** Schematic course of internal copulatory duct system, dorsal view. Abbreviations: CD = copulatory duct; CO = copulatory opening; DP = dorsal plate of the epigyne; FD = fertilization duct; S = spermatheca; VP = ventral plate of epigyne. **A, B, E, F** were modified from Xu et al. (2021). Scale bars: 0.30 mm (**A–H**).

(30.0°N, 101.9°E), 14 Jul. 2004 • 1♀, Luding Co., Moxi Town, Yajiageng Valley (29.6°N, 102.1°E), 20 Jul. 2004 • 2♀, Jiulong Co. Wuxuhai Nature Reserve (29.0°N, 101.5°E), 26 Jul. 2004 • 2♀, Xiaojin Co., Changpinggou Valley, Mt. Siguniang (31.1°N, 102.9°E), 1 Aug. 2004. All paratypes collected by X. Xu et al.

Other material examined. • 1♂4♀ (SYNU-Ar00448–52), **China**, Sichuan, Xichang, Anha Vill., near Yellow Dragon Pond (27.589792°N, 102.300279°E, 3759 m), 8 Jun. 2024, X. Zhang et al. leg.

Note. Cheliceral stridulatory striae present in the male, vestigial in the female.

Discussion

With more new pimoid species being discovered in the Pan-Himalaya, it has become a diversity center of pimoids (WSC 2024). However, the map of Asian pimoids reveals that there are still large areas where pimoids have not been recorded (Fig. 1), such as eastern Tibet, western Sichuan, and southern Qinghai. Therefore, we believe that more new pimoids will be reported with further collections. We have recently collected abundant pimoid specimens in the Pan-Himalaya, and further molecular systematic research in pimoids will shed more light on true species diversity and diversification processes in this region.

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